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Physiology Tutorials Using Causal Concept Mapping

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Abstract

We have developed a suite of tutorial programs in physiology based on causal concept maps. A causal concept map represents a set of causal relationships in a directed graph. Our package consists of three major parts: a tutorial on causal relationships and an exercise in concept map building, a CIRCSIM concept map tutorial, and a GASP concept map tutorial. Students build concept maps that represent the causal relationships between important parameters in physiology. The program guides the students by providing them with hints while they are constructing the concept maps. Concept mapping is known to facilitate the learning process in many educational environments.

Introduction

One of the core problems in medical education is how to teach a vast amount of information effectively within the limited amount of time and space that medical schools can find room for in their curricula. We have built a Causal Concept Mapper package in order to help both faculty and students deal with this problem. The Causal Concept Mapper is a series of concept mapping tutorials in which students build concept maps to help them gain mastery of the subject matter and understand the relationships between concepts. We have also developed concept mapping tools for the expert to support curriculum development and to help faculty members build new concept mapping tutorials for their students more easily.

Our goal in the building of student tutorials is to use concept maps to help students organize and master a huge quantity of information from many different sources and understand the relationships between different sciences, both basic and clinical. Concept maps can be used to categorize and organize the major concepts in a readily accessible form. When a student learns a concept, it is accomplished by connecting the new piece of information to the knowledge already acquired in the past (Novak, 1998). In a student's knowledge space, the acquired concepts are related each to other by the meanings of the words describing the concepts. Concept maps help this process of learning by introducing a graphical representation of concepts and their relationships. A concept map is basically a connected graph of concept labels and the relationships between them. These maps are used to teach important concepts and to help students understand them by presenting the relationships between those concepts in a visual way. Concept mapping techniques have been widely used in many fields, such as education, psychology, sociology, politics, economy, and computer science. Concept maps have been proved to be especially useful in the assessment of students' learning in schools.

Causal Concept Maps

Tutorials Using Causal Concept Mapping

Figure 1 and Figure 2 illustrate the tutorials that we have built for medical students based on concept maps in two areas of physiology. These tutorials are designed to teach topics like the baroreceptor reflex system and the two interlocking negative reflex regulatory systems for respiration. These tutorials are designed to help the students understand the

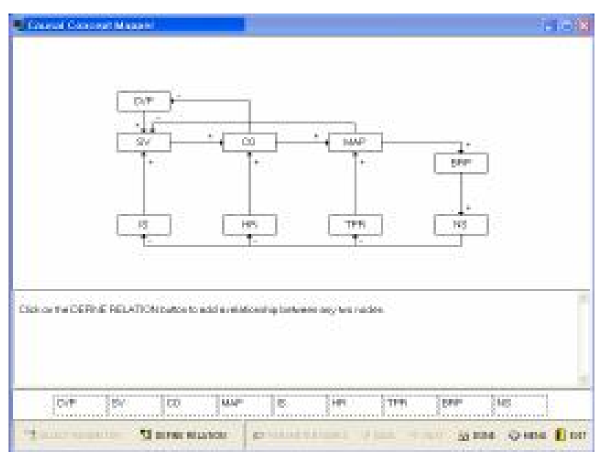

Figure 1. CIRCSIM Concept Map Tutorial.

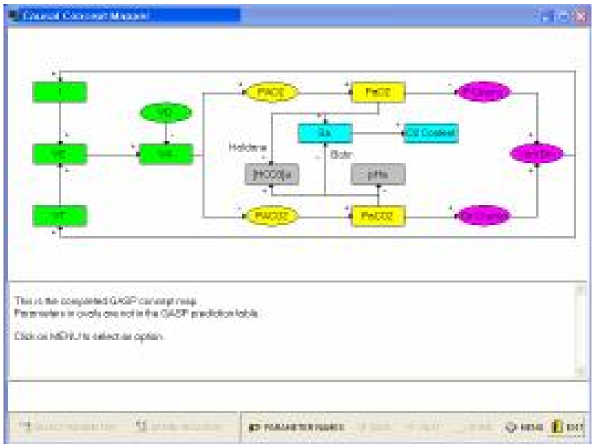

Figure 2. GASP Concept Map Tutorial.

materials better by experimenting with the concept maps. We are using causal concept maps to support qualitative causal reasoning processes in physiology.

The first program in our tutorial series explains the process of causal reasoning to help students better understand the ways of defining relationships between the parameters. Figure 3 is an example showing the causal relationships among three different parameters. The arrow between the parameters indicates the direction of the causal effect, and the sign on the arrow specifies the causal relationship between the parameters – *direct* or *inverse*. An exercise following the tutorial allows students build a simple concept map, using an example of CARROTS-RABBITS-FOXES population change. The tutorial reacts intelligently to students by providing appropriate hints when they create a wrong connection or indicate a wrong relationship.

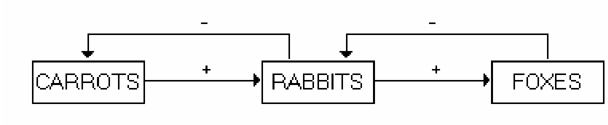

Figure 3. Causal Relationships.

For example, when an incorrect sign is selected for an inverse relationship between A ›B, the tutorial displays a hint message saying "If A changes, B tends to change in the opposite direction."

CIRCSIM Concept Map Tutorial

The second section is a concept map tutorial for the top level of the CIRCSIM knowledge base. CIRCSIM-Tutor (Kim *et al*., 1989; Khuwaja *et al*., 1992) is an intelligent tutoring system to teach first year medical students about the effects of perturbations to the cardiovascular system. In the cardiovascular system, a negative feedback mechanism reacts to the perturbations and stabilizes blood pressure. The baroreceptors in the neck monitor the blood pressure and report the changes to the central nervous system. CIRCSIM-Tutor teaches students how this negative reflex mechanism works and how to use causal reasoning about the parameters in solving problems. Through our tutorial, students come to understand the cause and effect relationships involving each individual, but mutually interacting, component of the cardiovascular system.

The knowledge base models of the cardiovascular system are qualitative causal models consisting of three levels - top level, intermediate level and deep level. The top level of the knowledge base corresponds to a concept map representing the baroreceptor reflex / central nervous system and the seven parameters whose behavior the students are asked to predict in a qualitative fashion.

The CIRCSIM Concept Map Tutorial (Figure 1) is an updated version of the previous work (Jeong *et al*., 1998; Jeong., 1999). The concept map for the top level CIRCSIM knowledge base contains nine parameters and thirteen relationships. Students build the concept map by inserting parameter nodes and then linking them by appropriate relationships. Each step is monitored to check the correctness and to provide a helpful message depending on the student's action. Students can check their progress by looking at the number of nodes and relationships remaining while building the concept map. At the end of the tutorial, a record is made of the total score for the use of the instructor.

Some examples of the messages given in the tutorial are:

If SV changes, CO tends to change in the same direction since CO = SV x HR.

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The rate at which the baroreceptors fire determine the level of stimulation of the CV control centers in the medulla. Increased baroreceptor firing increases the stimulation of the CV centers.

Increased stimulation of the NS (which results from increased MAP) causes the autonomic nervous system to decrease TPR.

Changing CVP directly changes the filling of the ventricles and thus causes SV to change in the same direction.

Messages of this kind are popped up whenever the students make errors to encourage them to correct any misunderstandings about the relationships by providing the required background knowledge. While the visual arrangement of the parameters and their relationships give students better understanding of the materials, the messaging system provides supplemental reminders about the underlying knowledge.

Concept Map Builder

We also developed programs for building concept maps for use in curriculum development. The starting screen of the expert version of the concept map builder (Figure 4) allows the user to define new relationships as well as new nodes based on the subject content matter.

The concept map builder supports several different modes of relationships, including the causal, anatomical, and general modes. The causal mode represents the direct and inverse relationships between concepts used in causal reasoning. The anatomical mode includes 'isa', part-whole, and spatial relationships between anatomical objects. In the general mode, we can define various kinds of relationships for concept maps.

Watson (1989) discusses ways to integrate concept maps into the curriculum. Edmondson (1994) uses concept maps in the development of problem-based learning modules. Examples can be found at the Department of Agriculture website. The expert version of the concept mapping program can also be used as the basis for building a new student tutorial. The authoring tool for building concept map tutorials is still in progress.

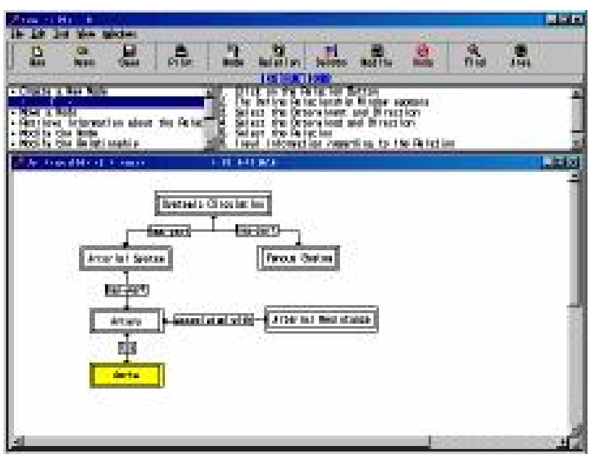

Figure 4. Concept Map Builder (Jeong, 1999).

GASP Concept Map Tutorial

The third section includes a concept map tutorial for the top level of the GASP knowledge base (Rovick and Michael, 1989). The two parameters in the respiratory system, arterial PO2 and O2, are regulated by alveolar ventilation, that is, by tidal volume and breathing frequency. There are large number of causally related parameters in the system, and two reciprocally responding negative feedback mechanisms play an important role. In addition, students often find the chemical components involved quite confusing. As with the baroreceptor reflex system in CIRCSIM, students can learn to make qualitative predictions about the responses of the respiratory system to the perturbations.

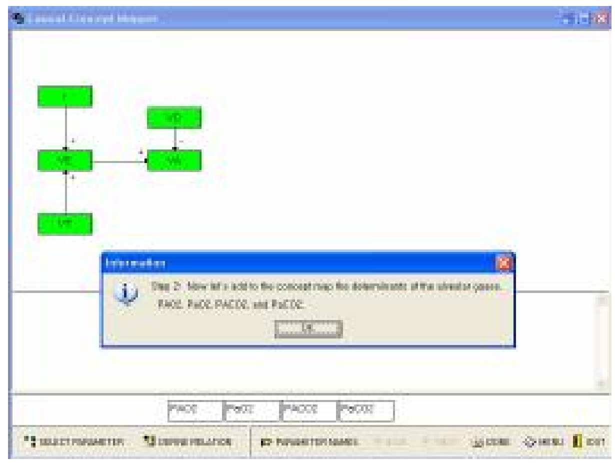

Figure 5. An Example of a Divided Concept Map in the GASP Concept Map Tutorial.

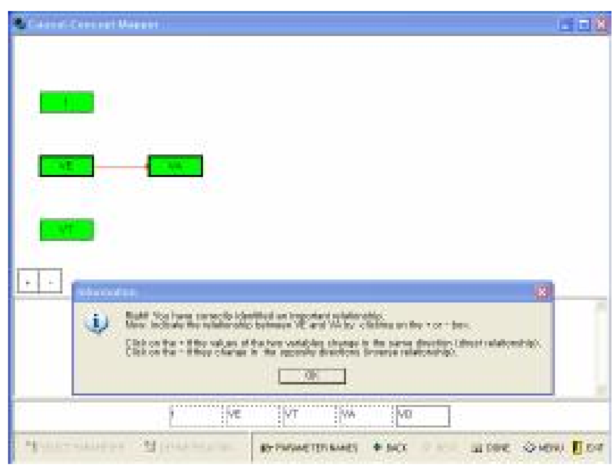

Figure 6. Defining a Causal Relationship in the GASP Concept Map Tutorial..

The GASP Concept Map Tutorial consists of six stages reflecting the different steps coordinated in the respiratory system.

1. Ventilation (Green)
2. Blood Gases (Yellow)
3. Control of Ventilation (Purple)
4. Oxygen Transport (Cyan)
5. Carbon Dioxide Transport (Gray)
6. Haldane and Bohr Effects (Text Labels)

The parameters in each stage are color-labeled to help students distinguish the different stages (Figure 2). This incremental approach to building concept maps helps students learn complex physiological system. At each stage, students are also provided with useful messages when they make any errors.

As in the CIRCSIM Concept Map Tutorial, students learn a physiology topic by building concept maps, but in separate steps (Figure 5). Every action in the construction process is monitored, and there is also a help message system that reacts to any student error in selecting parameters or in defining the relationships (Figure 6). Students can access hints on the remaining number of nodes and relationships at any time.

The messages displayed during the tutorial session are comprehensive enough to include almost every possible mistake students can make in building the concept maps. We are in the process of adding more messages to the GASP Concept Map Tutorial.

Conclusion

We have built tutorial programs for medical students learning physiology. These tutorials are based on causal concept maps. The concept maps use multiple stages with multiple colors which may facilitate students learning. The effectiveness of using these techniques still needs to be proven in a real environment.

The concept map builder in progress promises an intelligent authoring tool for making tutorials based on concept maps. We will be able to include the messages with conditions in concept maps for tutoring students. This means we can build a concept map with comments or messages embedded in each node or relationship and then use the map as a basis for an intelligent tutor.

The problems of medical education are complicated by constant changes in this vast body of knowledge as new discoveries in both basic and clinical sciences make their way into the medical curriculum. We have tried to meet these problems by exploring approaches to building concept maps automatically from the index of medical textbooks.

Using concept mapping techniques, it is possible to construct concept maps from medical textbooks using index terms as major components of concepts. The resulting concept maps will serve as guides to the instructors in curriculum design as well as tools for learning to the students. We have extracted the index terms from *Harrison's Principles of Internal Medicine* (Isselbacher *et al*., 1994), and are experimenting with organizing the terms in a number of different ways (Kim *et al*., 2001).

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